

Formation of phase composition of petroleum bitumen according to data of temperature modulated differential scanning calorimetry

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Abstract The analysis of structural and thermal properties of petroleum bitumen is carried out by temperature modulated differential scanning calorimetry. The technique allows to separate equilibrium and non-equilibrium thermal events and makes it possible to identify and observe structure transition invisible or overlapping on curves of conventional differential scanning calorimetry. It is shown that bitumen is a dispersion system only in specific time–temperature conditions. The dispersed phase can be represented by two types of aggregates. Saturates form aggregative solid, structural crystalline phase in accordance with thermodynamic law of structural phase transitions and nucleation thermodynamic mechanism of phase separation. The asphaltenes form for a relatively long time, an aggregative solid structurally amorphous phase as a result of thermokinetic structural relaxation glass transition by spinodal thermodynamic phase separation mechanism.

Keywords Bitumen · Temperature modulated DSC · Dispersed system · Phase and relaxation transition

Introduction

Insufficient information about the phase transformation and time–temperature conditions formation of supramolecular structures in bitumen makes it difficult to recognize the required parameters and technological properties of bituminous material at all stages of its production and operation [1–4].

It is generally accepted [5] that petroleum bitumen is a colloidal dispersed system with a solid phase aggregates of asphaltenes, dispersed in environment of maltenes (a mixture of saturates, aromatics, and resins). Formation of such system is based on the structural transitions which are different in nature due to the complexity of the components composition and structure [6]. They can be grouped into two classes—phase and relaxation [7]. Phase transition is change of structure from less ordering to more orderly conditions (and vice versa). The relaxation transition is not bounded by degree of structures ordering but demarcates the state of material by ratio of relaxation time and external action. Separation of transitions in the bitumen is a non-trivial problem, because relaxation phenomenon defines the main consumer properties of bitumen, it will inevitably influence on phase transitions, which, in turn, will affect on the relaxation processes.

In present work, for studying phase compositions of petroleum bitumen, temperature modulated differential scanning calorimetry (TMDSC) was used [8–10]. The technique allows to separate relaxation thermokinetic processes of glass transition from thermodynamic phase processes of melting and crystallization. With TMDSC, the total heat flow is deconvoluted into the heat capacity-related reversed heat flow and the kinetics-related non-reversing heat flow [11]. The total heat flow is equivalent to the conventional DSC signal [9]. Reversing curve is a

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